Explanation of the Slide Set

The following figures were originally presented at the AGU Chapman Conference on the Magnetotail which was held in Kanazawa, Japan on November 5-9, 1996. They show the first energetic neutral atom image results from Polar. Since the presentation was originally an oral talk there are minimal descriptive words associated with each figure. This text provides a more detailed explanation of each figure.

You can navigate through the document in three ways. (1) You can use the next and previous page buttons in the toolbar at the top. (2) You can click on the figure number given in this document. Or (3) you can click on one of the thumbnail images on the left to immediately go to that figure.

Background

Figure 1. Title Slide.

Figure 2. Overview of the CEPPAD instrument on Polar. The instrument that we use for the neutral particle imaging is the Imaging Proton Spectrometer (IPS). Recently we have lowered the minimum threshold energy on IPS to ≈13 keV to make the instrument even more sensitive to neutral atoms.

Figure 3. IPS schematic. The IPS consists of three telescopes each of which has three active solid state detector areas. Thus there is a total of nine polar angles each of which is approximately 20° wide. The detector field of view spins with the spacecraft and data are taken in 32 azimuthal bins. This gives excellent angular resolution on the unit sphere.

Interval 1: August 29, 1996 - Storm Time Response

Figure 4. The IPS Spectrograms (Flux vs. Energy and Time) for 5 of the 9 IPS detector heads. The data are averaged over azimuthal angle. The plot covers 24-hours of time. It begins with Polar in the high-latitude nighttime plasma sheet. Polar then cuts through the plasma sheet and radiation belts where intense fluxes of high energy charged particles are observed. The radiation belts appear as a bright yellow and red hump. Polar then cuts across the southern polar cap (a narrow area with low fluxes) and back through the dayside radiation belts (the second hump). Polar then spends considerable time in the northern polar cap where the fluxes of energetic particles are quite low before again cutting through the plasma sheet and radiation belts (final two humps).

Figure 5. The IPS Roll Plots (Flux vs. Angle and Time) for the same 24-hour period. Here the radiation belts appear as bright bands cut by darker lines that are the loss cones. In the top panel there is a light blue line that cuts across the entire northern polar cap. This is thought to be the response of the IPS to scattered sunlight from earth. It can be used to identify the earthward-pointing direction in the plots. Just to either side of the earth line lie low-intensity fluxes that appear as dark blue pixels. This is the signature of energetic neutral particles. The energetic neutrals are produced by charge exchange of energetic radiation belt ions with the cold, extended, neutral atmospheric halo around the earth.

Figure 6. This figure is shows the orientation of Polar and the Earth. Polar is represented by a sphere which is divided into 9 polar and 32 azimuthal sectors which represent the IPS viewing directions during a single spin. (This is called the IPS viewing sphere.) The spin axis of polar is also shown. The grid represents the magnetospheric equatorial plane divided into squares that measure 2 Re X 2 Re. It is intended only as a reference to help define where IPS is looking. The red axis is the +X-axis and points toward the sun.

Figure 7 shows the viewing geometry as seen by IPS. The top panel is an angle-angle plot that again has the sectors numbered. The bottom panel shows the view of the Earth and the equatorial plane as seen by IPS. It may help to visualize this by imagining you are at the center of the viewing sphere shown in figure 6 and that you are looking out through the sphere at the Earth. The numbers again just label the sectors. This figure is also a useful reference for determining exactly what angles each IPS "pixel" corresponds to. The subsequent images will be shown in this format.

Figure 8 shows the actual ENA image for August 29. It represents a 45 min accumulation of energetic neutral atoms during a time when there were essentially no charged particles measured by IPS. The angle-angle plot clearly shows that the fluxes come from the earthward direction and that there is essentially no flux from any of the other directions. This helps confirm that the particles detected during this time are, indeed, energetic neutral atoms. The lower panel shows the actual image. The dark pixels at the Earth were originally saturated by reflected sunlight so those two pixels have been set to zero. The other pixels are color coded to represent the flux of ENAs in counts/second. The most intense fluxes are red and represent approximately 6 counts/s. This image clearly shows the presence of an enhanced, symmetric ring current. By looking at other intervals we have seen the intensity of the ring current grow and decay.

Interval 2: July 31, 1996 - Substorm Injection

Figure 9 shows the IPS spectrogram for this day.

Figure 10 shows the IPS roll plot. Notice in panel 3 of figure 10 that there is a burst of energetic neutral atoms that begins quite suddenly and then decays. Notice also that they do not come from the most earthward-looking direction (which would be either side of the earth line in the top panel). This burst of energetic neutral atoms is associated with a substorm injection. The substorm injection was observed directly by the LANL geosynchronous satellites (Fig 15) and the substorm was also confirmed with the VIS images (Fig 16)

Figure 11 shows the viewing geometry for this interval.

Figure 12 shows the angle-angle sector definitions and the IPS viewing sphere as described in Figure 7.

Figure 13 shows the ENA image for this interval. At this time Polar was much closer to the equatorial plane near the dawn terminator. The sun is located off to the right of this figure (as indicated by the red axis) and the ENAs are observed on the night side. Comparing the IPS pixels with the equatorial grid we see that the source ions that produced the energetic neutral atoms probably originated at 4-8 Re which is the region where substorm injections are observed to occur. This figure shows 45 minutes of accumulated data. The count rates are sufficiently high that we can get substantially better time resolution and actually watch the dynamics of the injection.

Figure 14 shows 12 angle-angle plots obtained during this interval. Each represents approximately 10 minutes of data. The injection is seen to come out of a low background, intensify, and then fade and become more distributed in angle.

Figure 15 shows four images produced from the data shown in Figure 14. Each is again a 10-min accumulation. Again we see the injection appear out of a previously low background and become quite intense. A movie of this sequence was presented at the meeting and is available at http://nis-www.lanl.gov/~mgh/ENA.shtml.

Figure 16 shows the same substorm injection as seen by the Los Alamos geosynchronous satellites. The onset of the injections corresponds very well to the appearance of energetic neutral atoms at Polar.

Figure 17 shows the auroral image from VIS (courtesy of Lou Frank). This image is from somewhat after onset and shows a very clear expanded auroral substorm bulge.

Figure 18 presents some concluding remarks.

First Energetic Neutral Atom Images From Polar

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Los Alamos National Laboratory

H. E. Spence, R. B. Sheldon, and A. M. Jorgensen
Boston University

J. B. Blake, and J. F. Fennell
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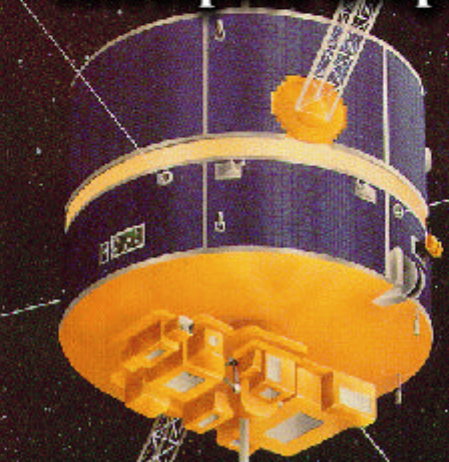
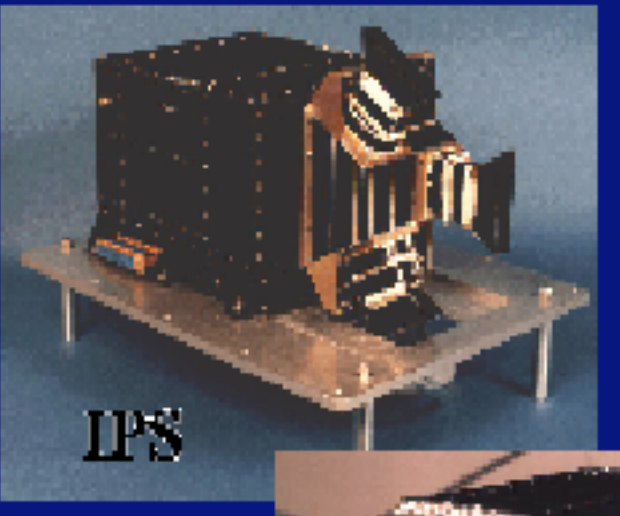


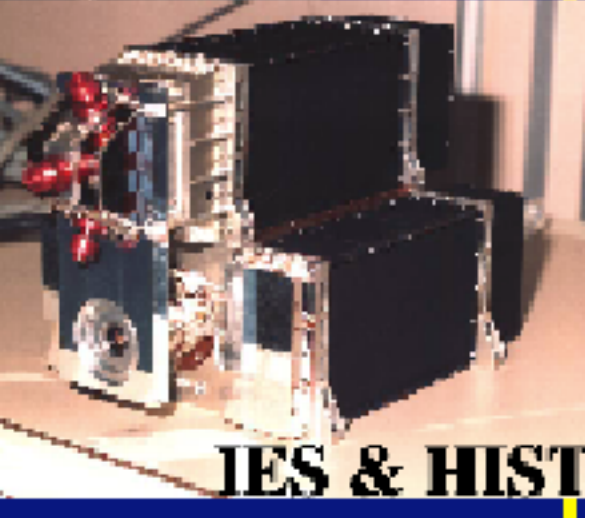
AGU Chapman Conference
on the Magnetotail
Kanazawa Japan, Nov 5-9, 1996

CEPPAD

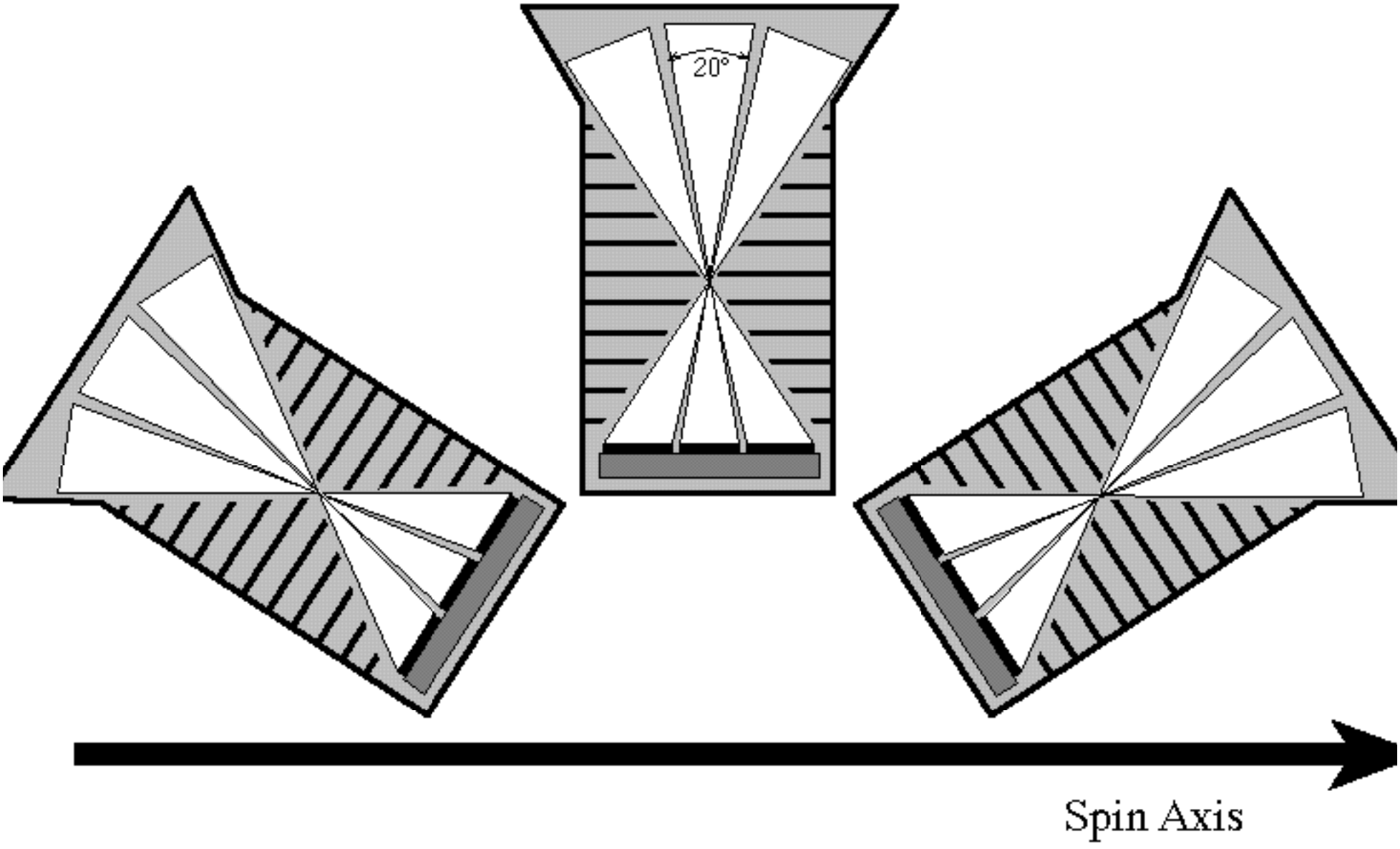
Comprehensive Energetic Particle Pitch Angle Distribution

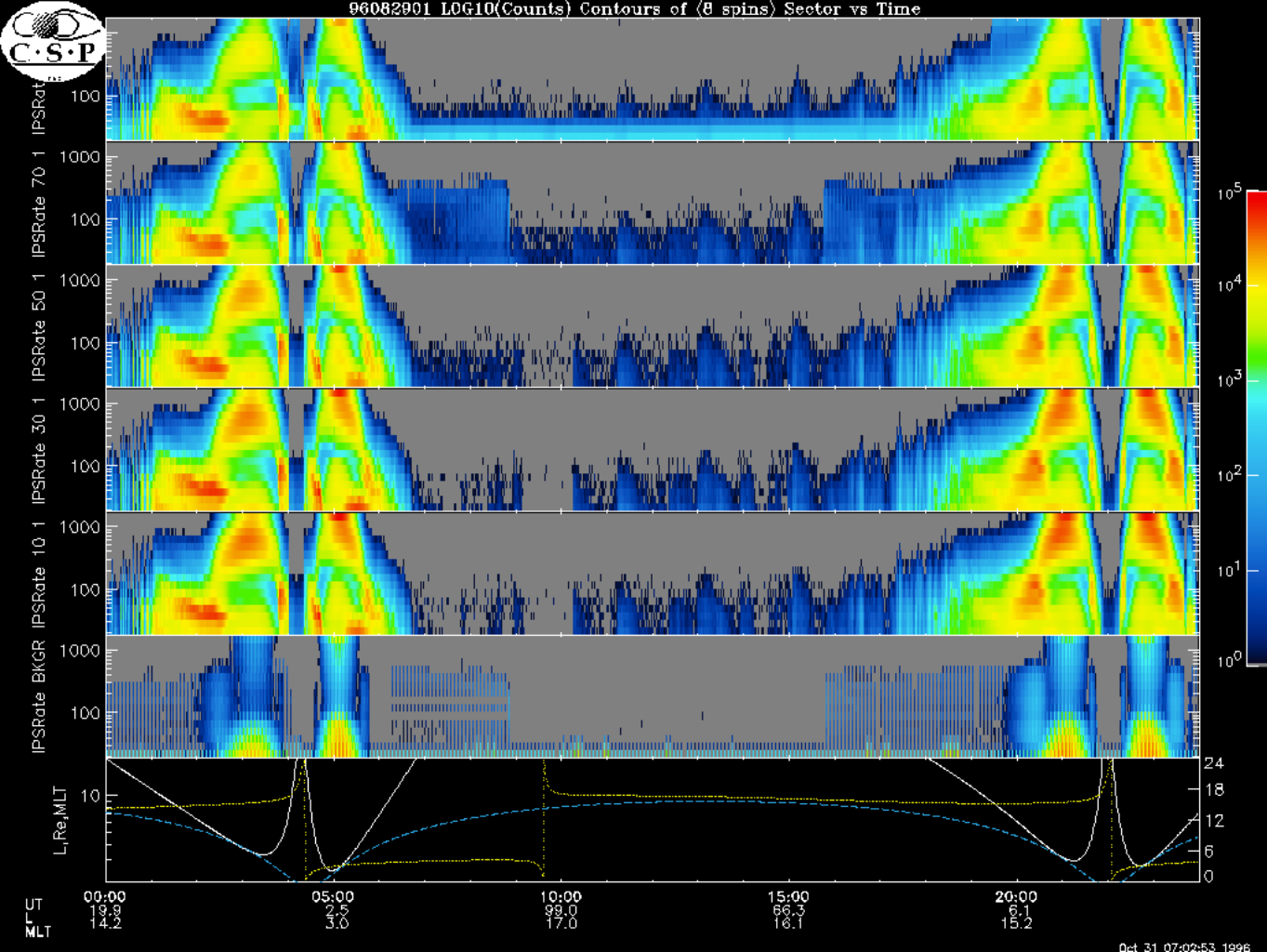
- IPS = Imaging Proton Sensor
  ≈20 keV to 1.5 MeV, 16 channels
  9 x 32 look directions
- IES = Imaging Electron Sensor
  ≈20 to 400 keV, 16 channels
  9 x 32 look directions
- HIST = High Sensitivity Telescope
  .3 to 10 MeV electrons
  3 to 80 MeV protons
- SEPS = Source/Loss-Cone Energetic Particle Spectrometer (despun platform)
  ≈20 keV to 2 MeV electrons 16x16 pixels
  ≈40 keV to 30 MeV ions, 16x8 pixels
  looks at ±B simultaneously





IPS Schematic

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IPSRate 50 1
IPSRate 30 1
IPSRate 10 1
IPSRate BKGR
100
1000
L,Re,MLT
10
24
18
12
6
0
00:00
05:00
10:00
15:00
20:00
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16.1
6.1
15.2
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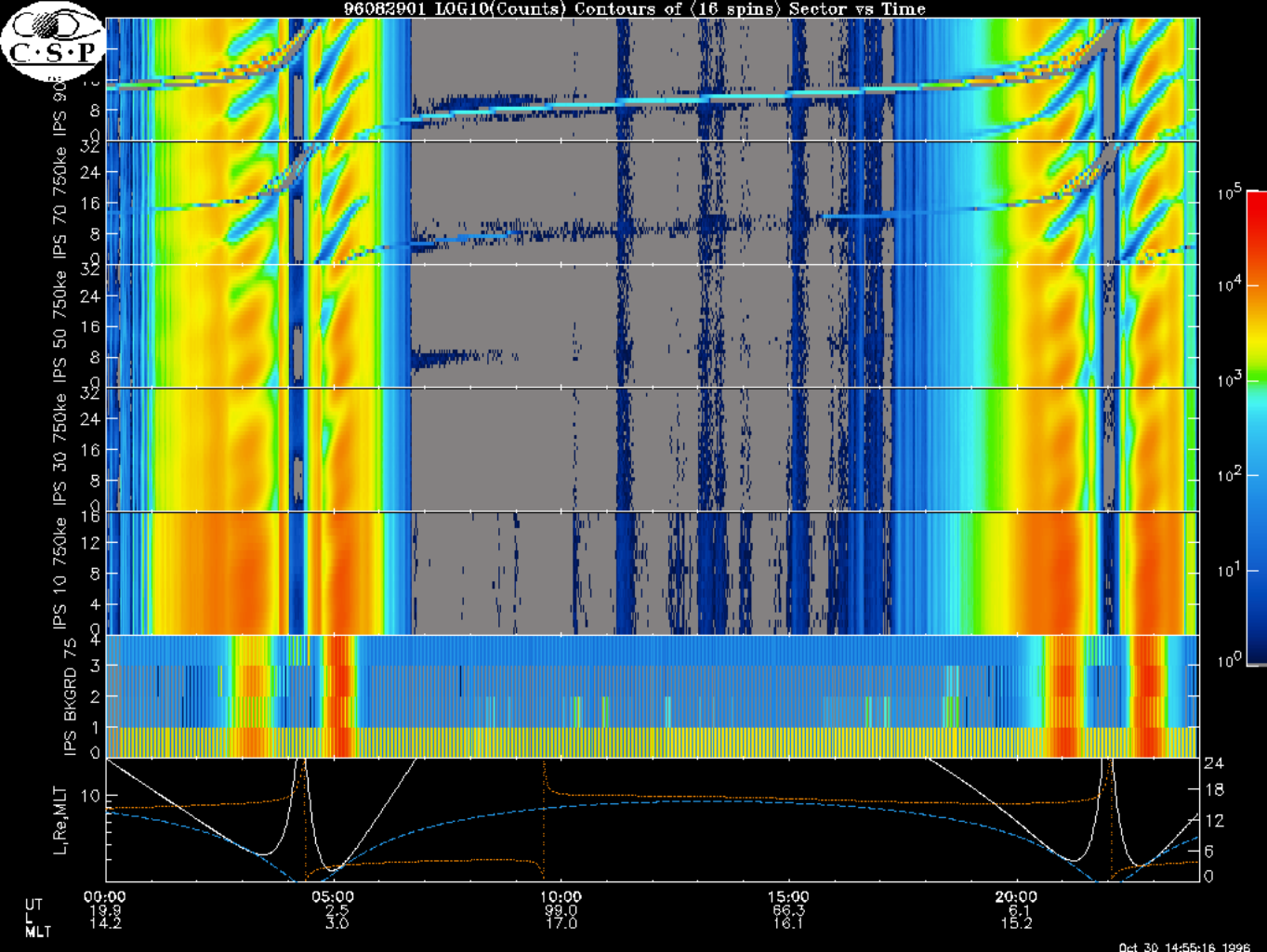
96082901 LOG10(Counts) Contours of (16 spins) Sector vs Time
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IPS 70 750ke
IPS 50 750ke
IPS 30 750ke
IPS 10 750ke
IPS BKGRD 75
L,Re,MLT
UT
L
MLT
00:00
19.9
14.2
05:00
2.5
3.0
10:00
99.0
17.0
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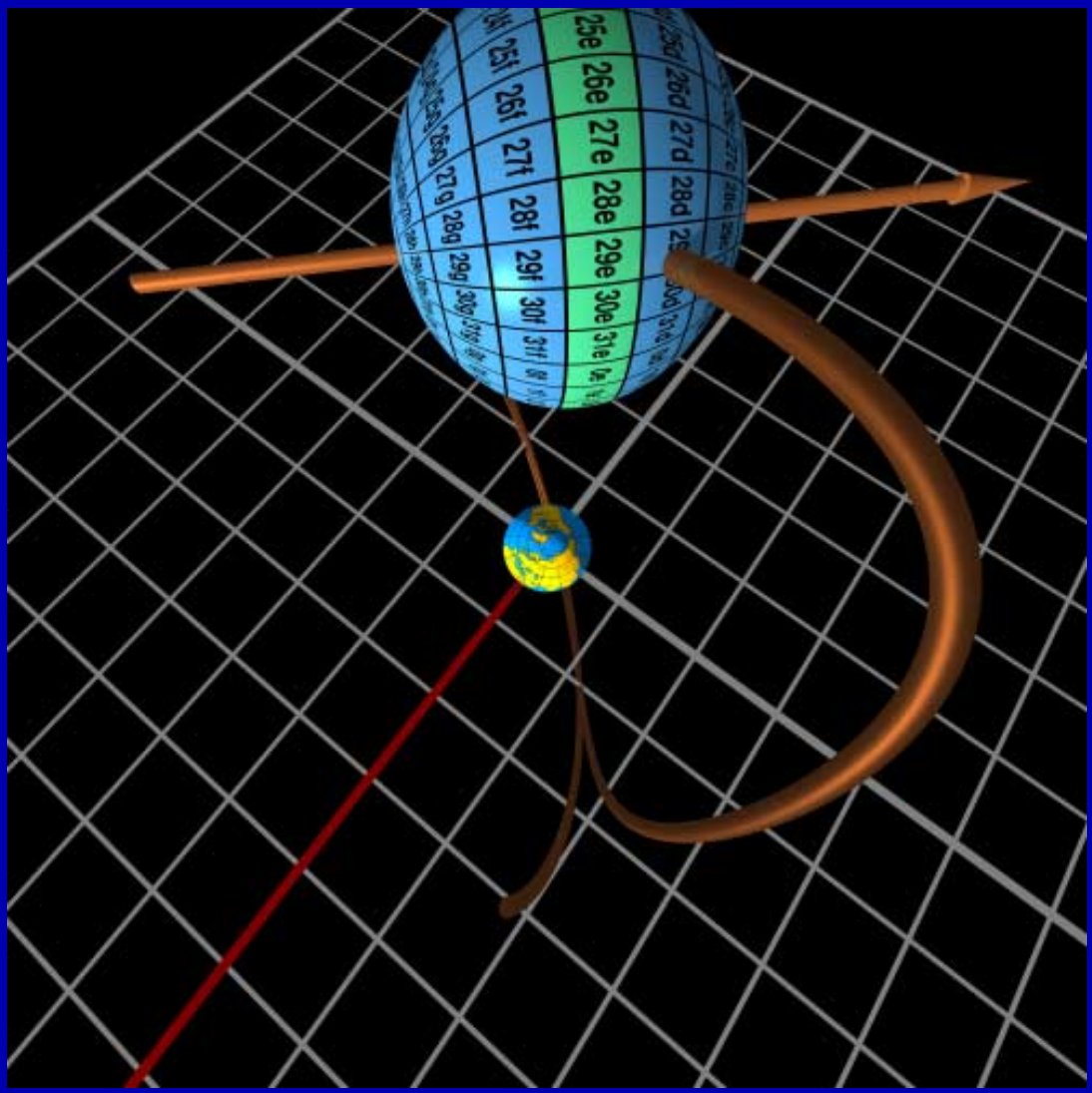
POLAR Attitude and Orbit
August 29, 1996 0938 UT



POLAR: View from IPS
August 31, 1996 0938 UT

Polar Angle

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30	31b	30b	29b	28b	27b	26b	25b	24b	23b	22b	21b	20b	19b	18b	17b	16b	15b	14b	13b	12b	11b	10b	9b	8b	7b	6b	5b	4b	3b	2b	1b	0b
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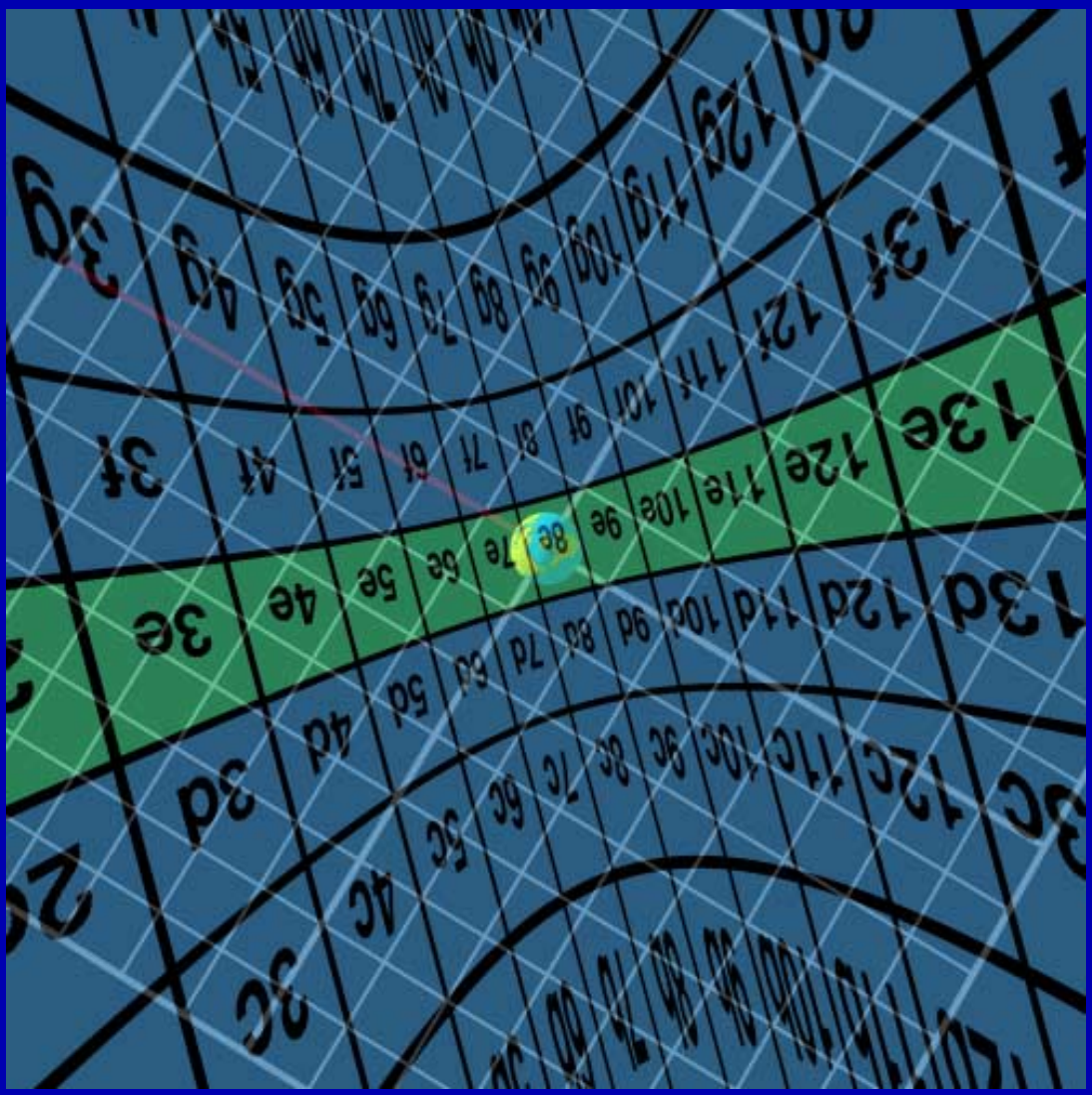
170	15i		14i		13i		12i		11i		10i		9i		8i		7i		6i		5i		4i		3i		2i		1i		0i	

Spin Sector

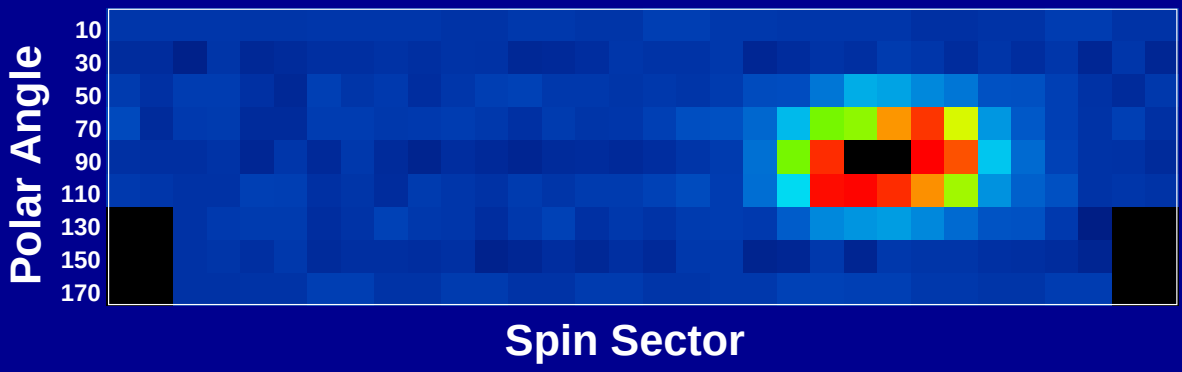


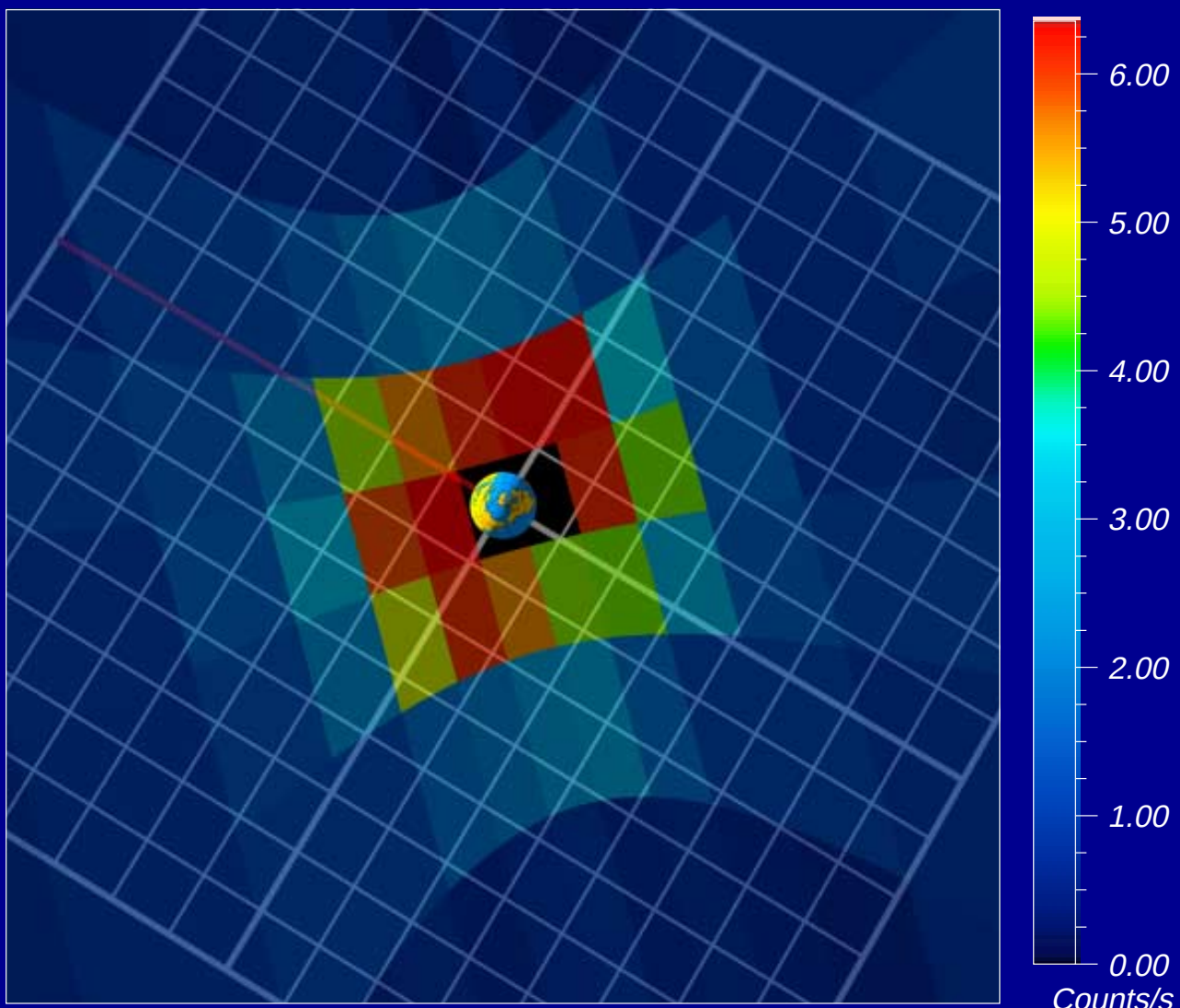
125 degree FOV

POLAR CEPPAD/IPS

Energetic Neutral Atom Image

August 29, 1996 (0915 - 1000 UT)





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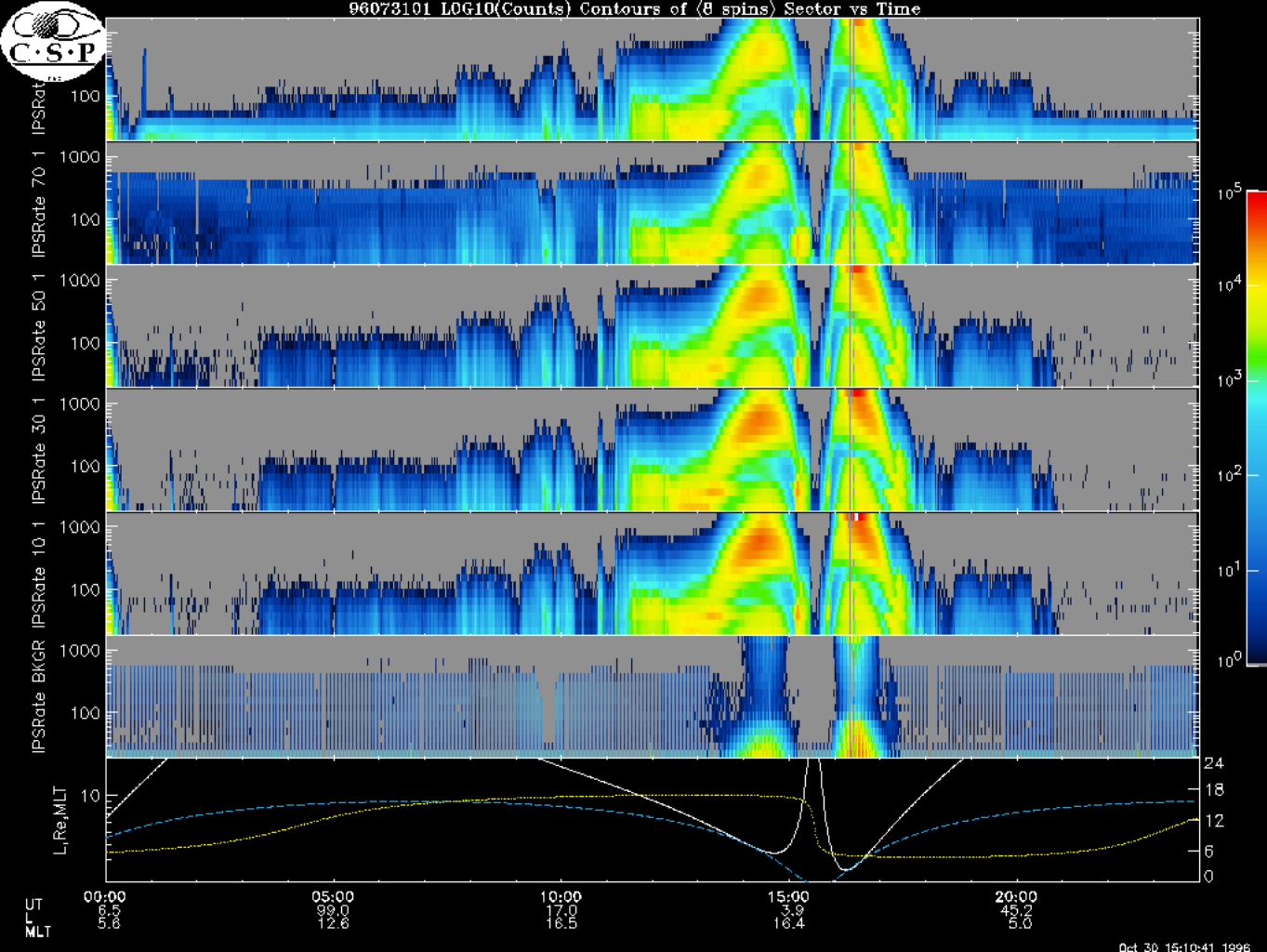
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IPSRate 70 1
IPSRate 50 1
IPSRate 30 1
IPSRate 10 1
IPSRate BKGR
100
1000
10^5
10^4
10^3
10^2
10^1
10^0
L,Re,MLT
10
24
18
12
6
0
UT
MLT
00:00
6.5
5.8
05:00
99.0
12.8
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3.9
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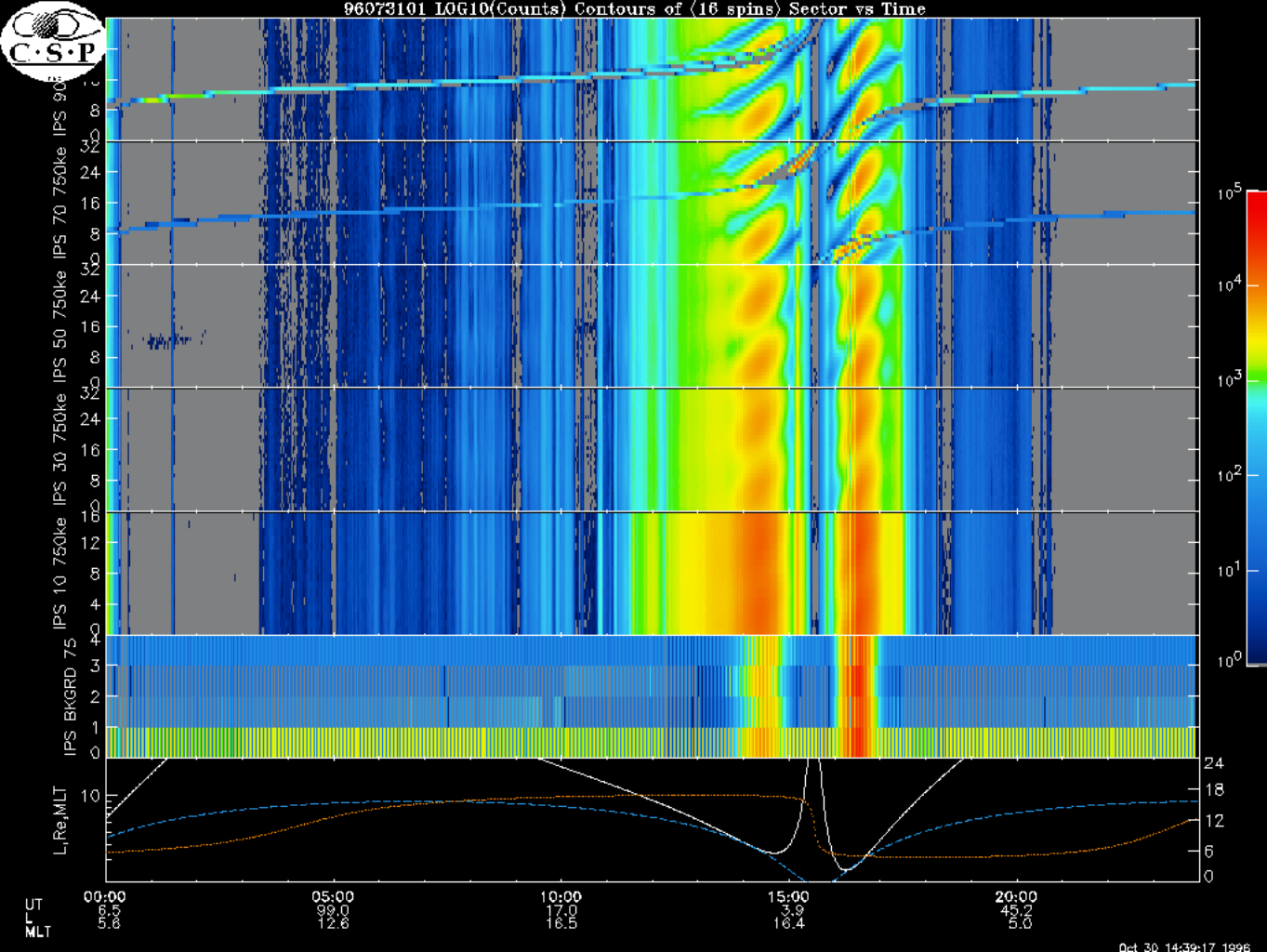
96073101 LOG10(Counts) Contours of (16 spins) Sector vs Time
C·S·P
IPS 90 750ke
IPS 70 750ke
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IPS 10 750ke
IPS BKGRD 75
L,Re,MLT
UT
L
MLT
00:00
6.5
5.8
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99.0
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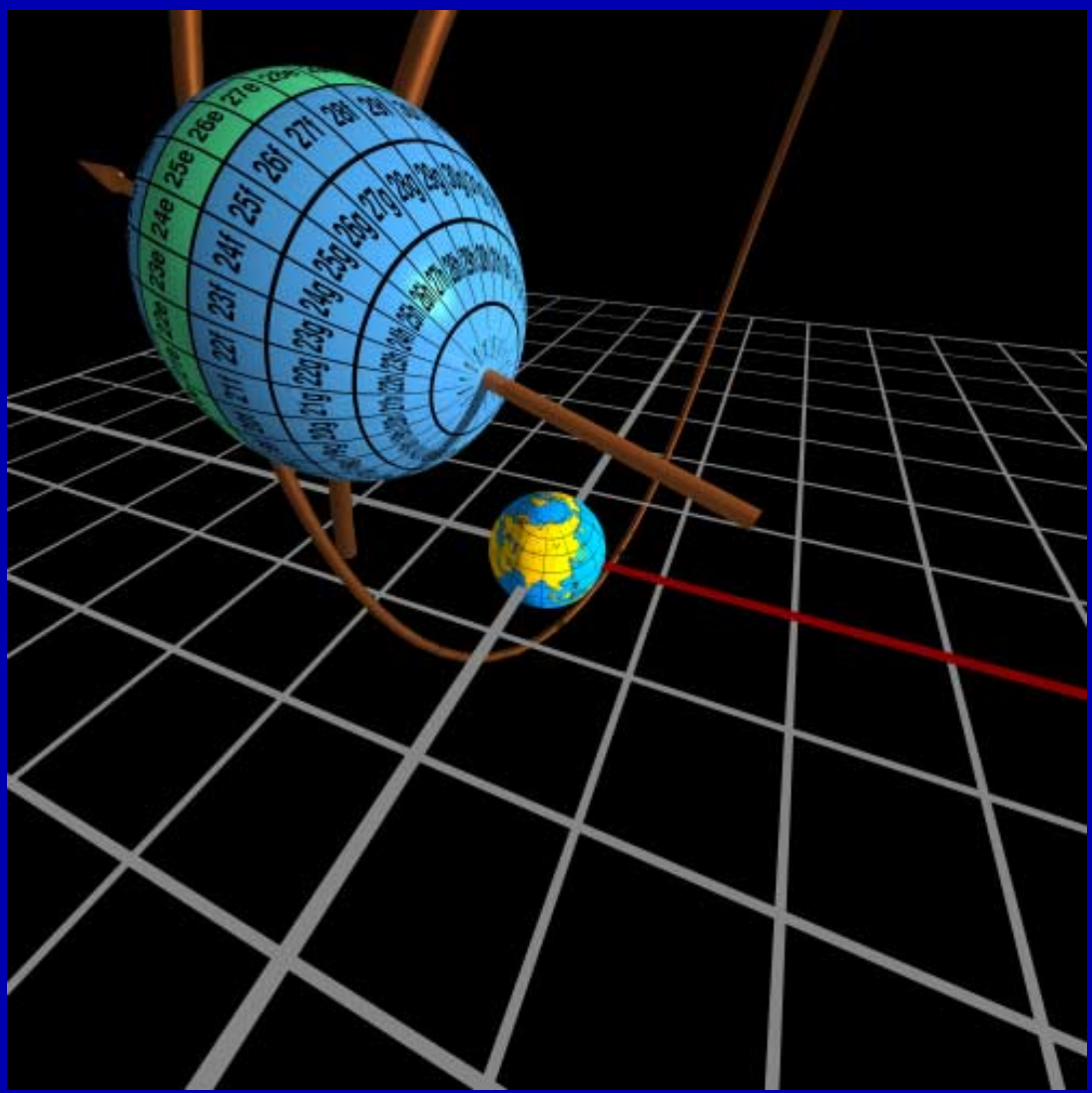
POLAR Attitude and Orbit
July 31, 1996 0105 UT



POLAR: View from IPS
July 31, 1996 0105 UT

Polar Angle																															
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170	15i		14i		13i		12i		11i		10i		9i		8i		7i		6i		5i		4i		3i		2i		1i		0i	

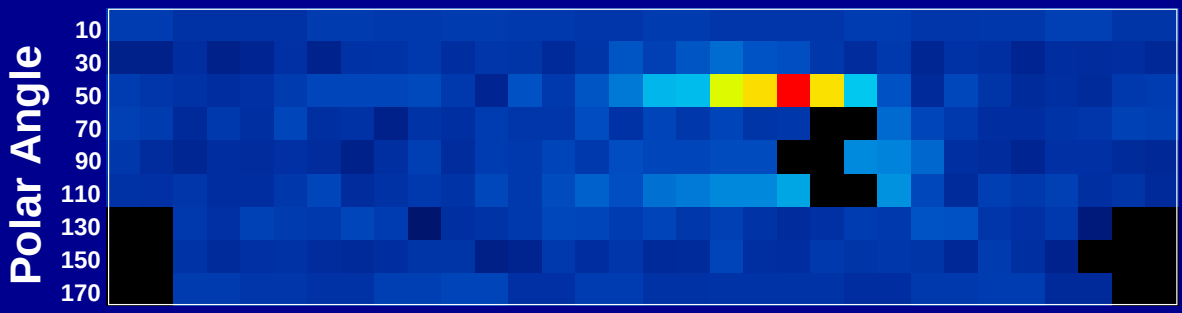
Spin Sector

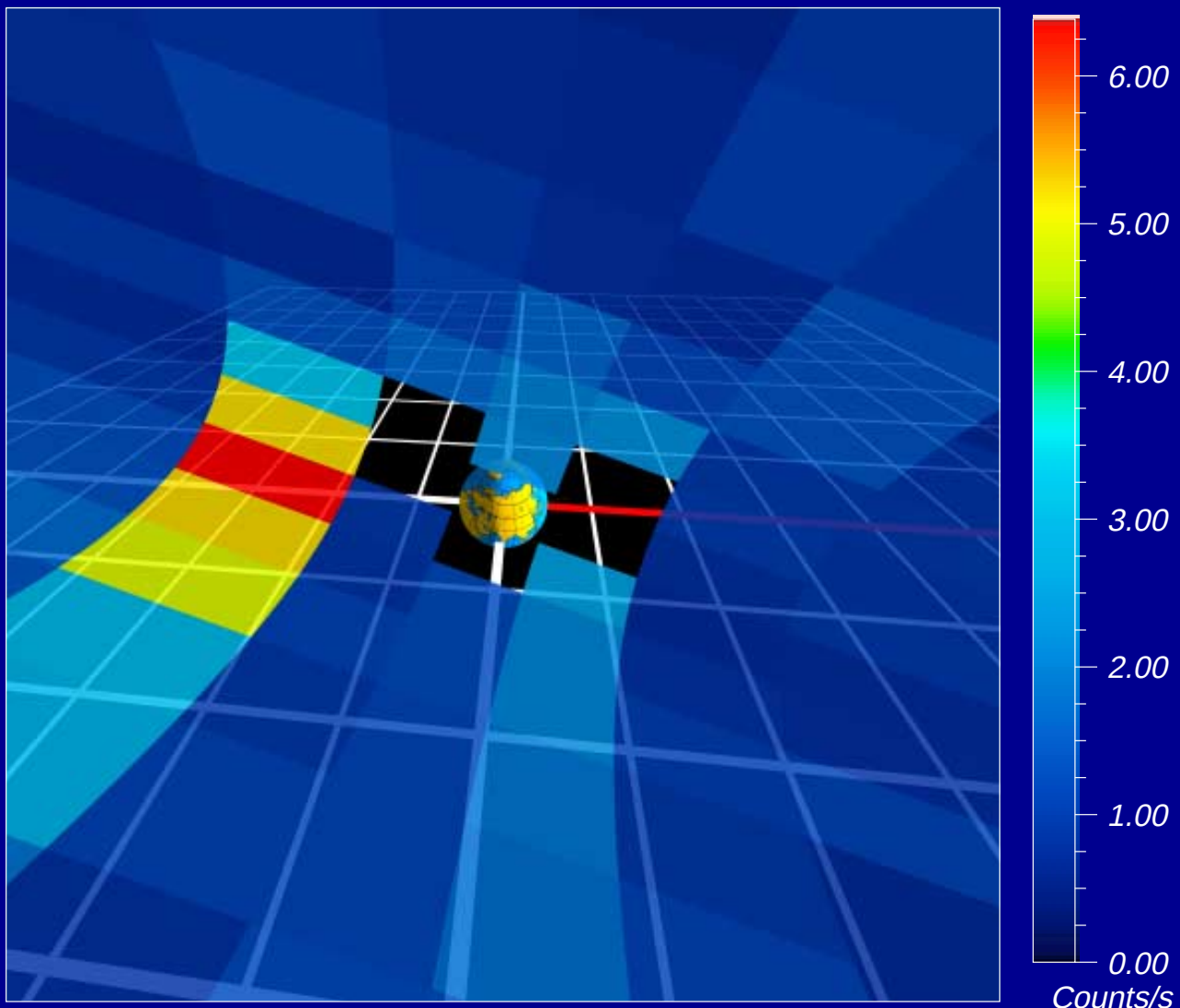
125 degree FOV

POLAR CEPPAD/IPS

ENA/Substorm Associations

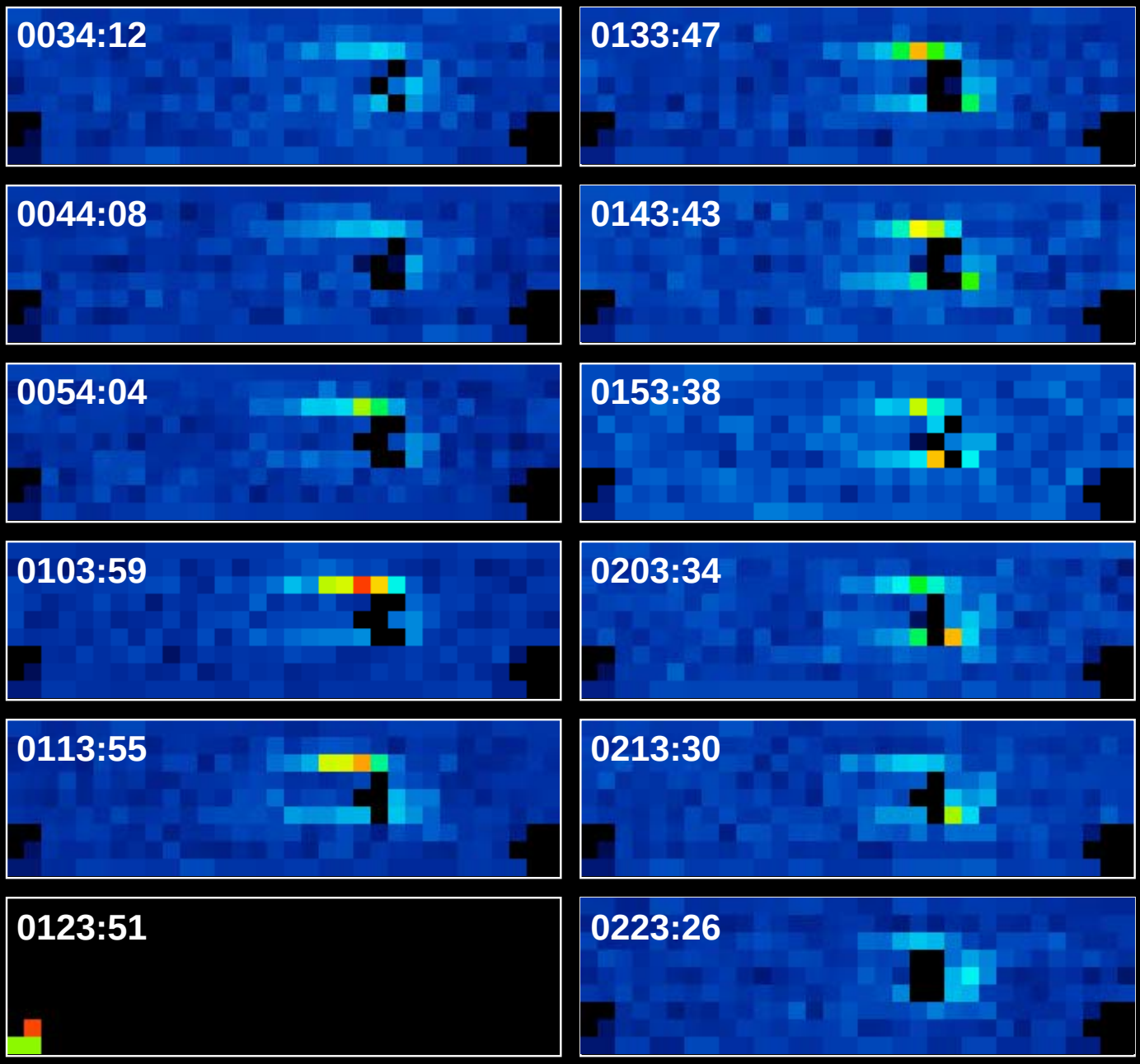
July 31, 1996 (0915 - 1000 UT)



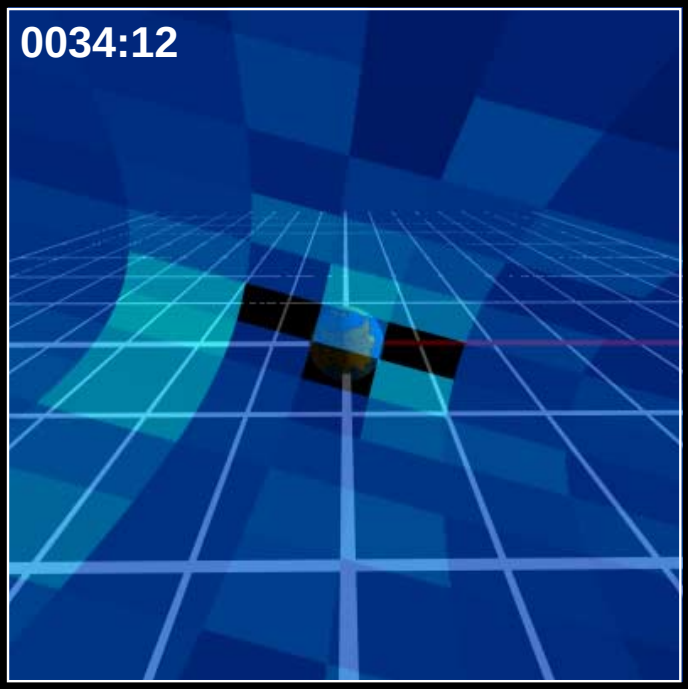


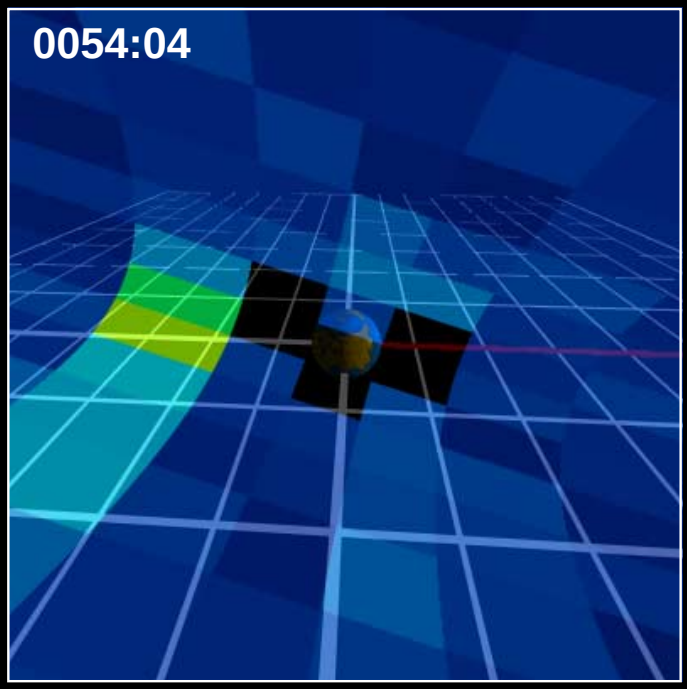
125 degree FOV

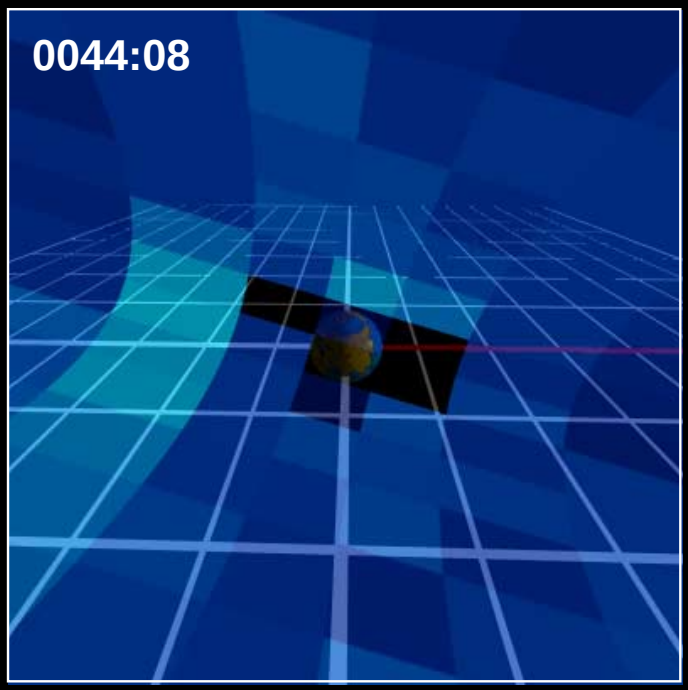
POLAR CEPPAD/IPS
Temporal Evolution of ENAs
July 31, 1996

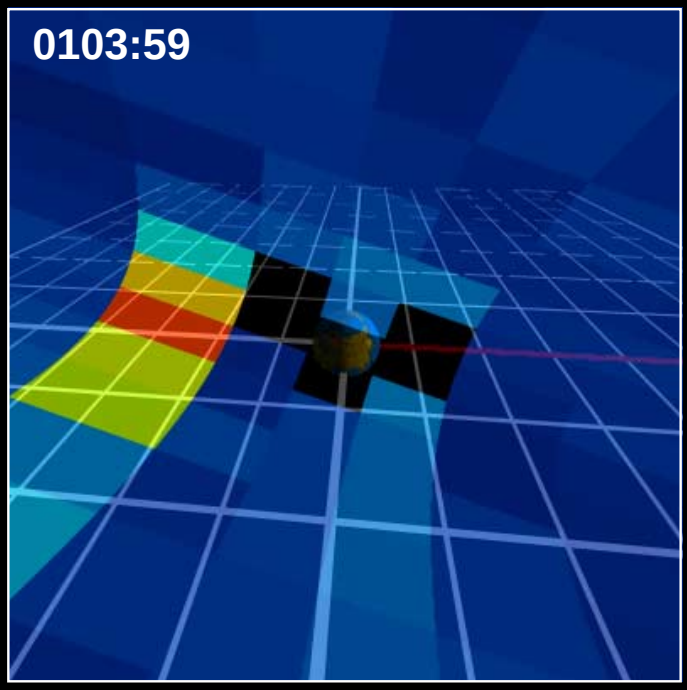


POLAR CEPPAD/IPS
Temporal Evolution of ENAs
July 31, 1996





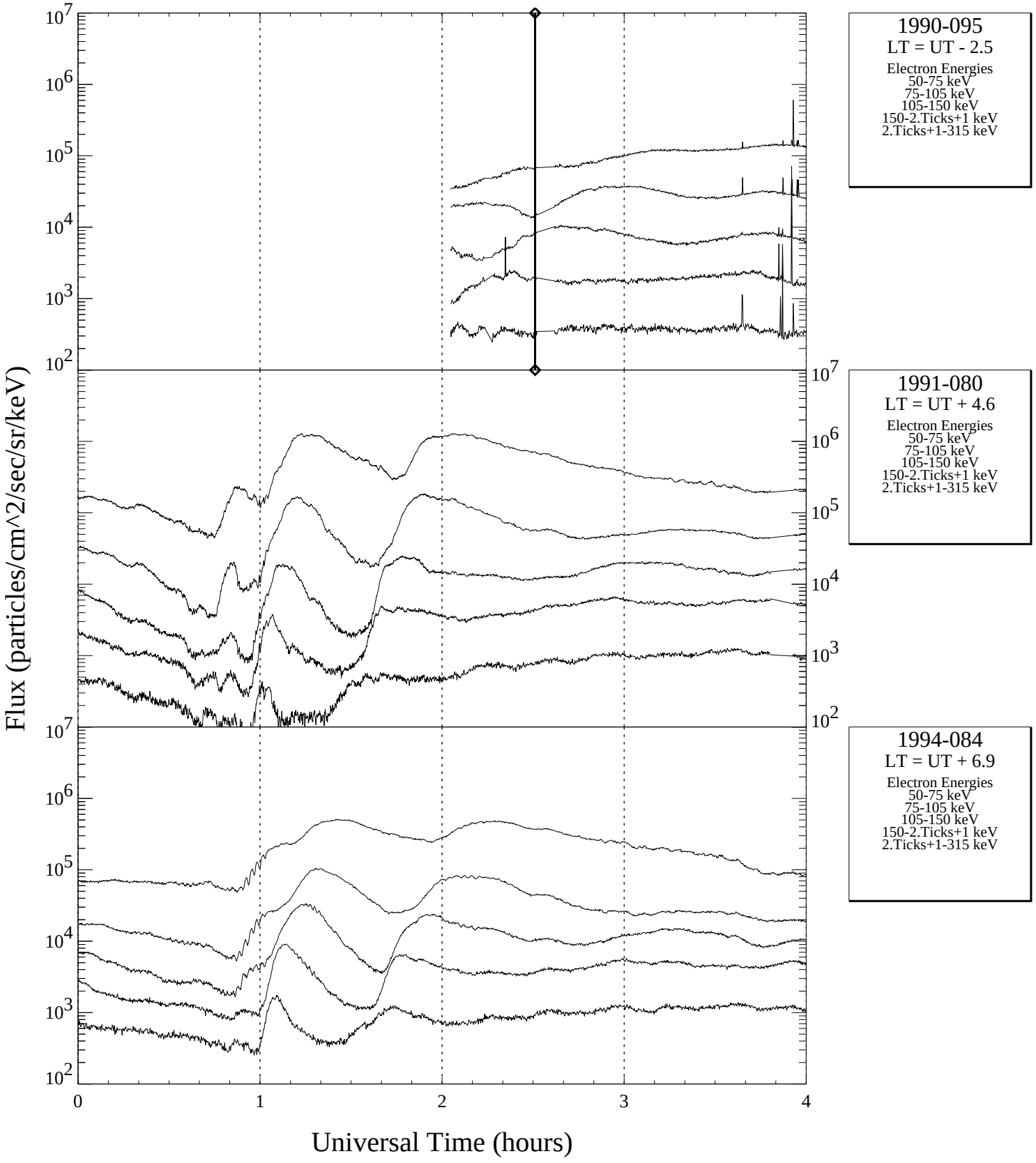


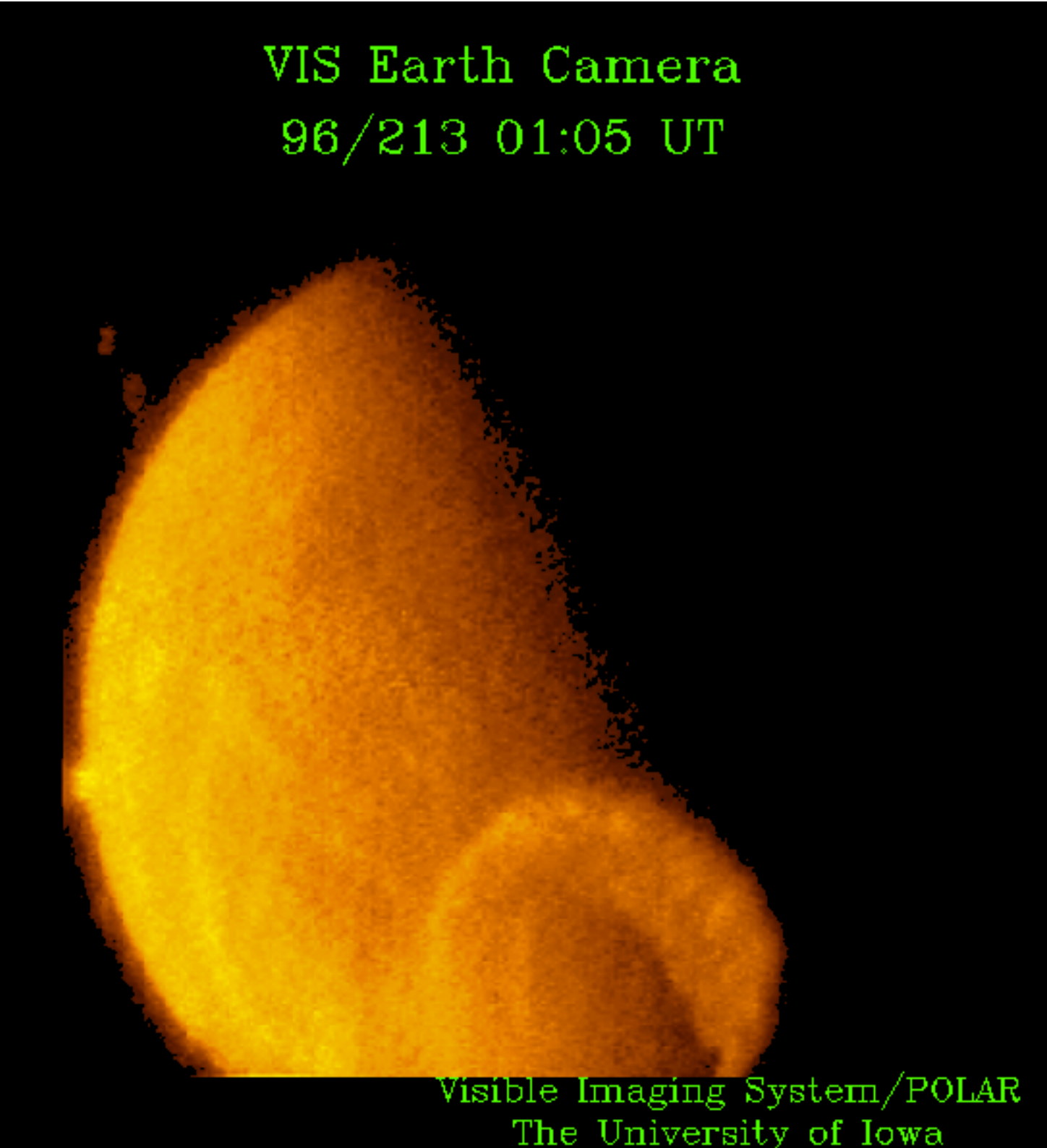


10 min. Integration Time
125 degree FOV

LANL Geosynchronous Energetic Electron Data

July 31, 1996




VIS Earth Camera
96/213 01:05 UT
Visible Imaging System/POLAR
The University of Iowa

Conclusions

- **ENAs Are Observed by IPS on POLAR**
  - Frequently
  - Easily
  - and with Reasonable Fluxes
- **First ENA Images from POLAR Shown**
  - Ring Current Development
  - Substorm Injection

    (consistent with VIS and LANL)
- **Much More to Come**
  - Movies
  - Better Spatial Resolution
  - Long-Term Dynamics
  - Spectral Studies
  - Neutral Oxygen (?)
  - Comparison with Models
  - Comparison with In Situ Measurements